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RICE (*Oryza sativa* L.) SEEDLING PERFORMANCE TREATED WITH GIBBERELLIC ACID AT DIFFERENT TEMPERATURES

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ABSTRACT: This work aimed to evaluate the initial performance of seedlings originated from seeds of rice cultivars treated with gibberellic acid and exposed to different growth temperatures. The cultivars SCS - 112, BRS 7-TAIM, BR IRGA 410 and IRGA 417 were used, soaked in concentrations of gibberellic acid of 0; 150; 300; 450; 600 and 750 mg L^{-1} and taken into germinator under temperatures of 15; 20 and 25oC. The evaluations were performed in relation to shoot and root of rice seedlings at 3; 7 and 21 days after sowing. The cultivars showed different dry matter production of shoot and root as gibberellic acid concentration, temperature and time of evaluation. The better initial performance of seedlings exposed to gibberellic acid shows the higher expression of the rice seeds vigor and demonstrates the superiority in efficiency of different physiological processes involved in the resumption of growth the embryo. Thus, gibberellic acid favors the growth of the rice seedlings over time.

Keywords: hormonal balance, initial growth, thermal stress, Oryza sativa.

DESEMPENHO DE SEMENTES DE ARROZ TRATADO COM ÁCIDO GIBBERÉLICO A DIFERENTES TEMPERATURAS

RESUMO: Este trabalho teve como objetivo avaliar o desempenho inicial de mudas originárias de sementes de cultivares de arroz tratadas com ácido giberélico e expostas a diferentes temperaturas de crescimento. Foram utilizadas as cultivares SCS - 112, BRS 7-TAIM, BR IRGA 410 e IRGA 417, embebidas em concentrações de ácido giberélico de 0; 150; 300; 450; 600 e 750 mg L^{-1} e ingeridos em germinador sob temperaturas de 15; 20 e 25^{o}C. As avaliações foram realizadas em relação à parte aérea e raiz das mudas de arroz aos 3, 7 e 21 dias após a semeadura. As cultivares apresentaram diferentes produções de matéria seca de parte aérea e raiz, como concentração de ácido giberélico, temperatura e tempo de avaliação. O melhor desempenho inicial de plântulas expostas ao ácido giberélico mostra maior expressão do vigor das sementes de arroz e demonstra superioridade na eficiência dos diferentes processos fisiológicos envolvidos na retomada do crescimento do embrião. Assim, o ácido giberélico favorece o crescimento das mudas de arroz ao longo do tempo.

Palavras-chave: equilíbrio hormonal, crescimento inicial, estresse térmico, Oryza sativa

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INTRODUCTION

The irrigated rice (*Oryza sativa* L.) is one of the main annual crops of Brazil and the world (ZHU et al. 2010), with national production exceeding 12,2 thousand tons. The optimum thermal amplitude for germination and initial growth of this cultivated species ranges from 25–30°C (BRASIL, 2009). Low air and soil temperatures during the sowing period negatively affect the initial growth of the irrigated rice seedlings. Vigor is a physiological process that involves the ability to reorganize the cell membrane system, and the hydrolysis, translocation and assimilation of the various structures of the seedling (AUMONDE et al. 2014; PESKE et al. 2012).

The adoption of new technologies and the study of different substances with the potential to increase the efficiency of physiological processes aimed at mitigating the effect of adverse environmental conditions become important for providing the most rapid and uniform establishment of rice seedlings (CARRAHER JR. et al. 2010; OLSEN et al. 2015: ESCALERA et al., 2019).

The rice cultivars used in the Brazilian state of Rio Grande do Sul, are derived from lineages that present a low concentration of endogenous gibberellin. This condition affects the process of resumption of embryo growth and the establishment of field seedlings (MIR et al. 2010: KOCK et al., 2018). Thus, the exogenous application of gibberellic acid has been reported as an alternative to low seed vigor problems (RIVERA et al. 2011), and may provide the best initial performance of rice seedlings when exposed to adverse environmental conditions. In this context, the current work aimed to evaluate the initial performance of irrigated rice seedlings treated with gibberellic acid and exposed to various growth temperatures.

MATERIAL AND METHODS

Location and rice seed cultivars

The work was conducted at the Laboratory of Seed Analysis of the Graduate Program in Seed Science and Technology at the Federal University of Pelotas, Brazil (31º52' S, 52º21' W; 13 m). Seeds of irrigated rice cultivars SCS-112, BRS-7 Taim, BR IRGA 410 and IRGA 417 were used.

Experimental design and treatments

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The experimental design was a randomized block with four replicates of 20 seeds, totaling 80 seeds per experimental unit in four statistical replicates.

Gibberellic acid solutions were prepared in distilled water at 0, 150, 300, 450, 600 and 750 mg L^{-1}. The seeds were separately embedded in the various gibberellic acid solutions and kept in a B.O.D. type germination chamber at 25°C, for 24 hours. After this period, the gibberellic acid solutions were drained and the seeds arranged to germinate in rolls of germitest paper, composed of three sheets moistened with distilled water at 2.5 times the sheet dry matter. The rolls were transferred to B.O.D. type incubation chambers at 15, 20 and 25°C, and for each temperature, a germination chamber (BRASIL, 2009).

Dry matter measurement

For determination of the dry matter, four samples of 10 seedlings were collected at 3, 7 and 21 days after sowing (DAS) and separated into the aerial part and root, which were then conditioned in brown paper envelopes and dried in a forced ventilation oven, at 70°C for 72 hours.

Statistical analysis

Data were analyzed by analysis of variance and the effects of treatments and interactions were evaluated by the F test. When significant differences at $p > 0.05$ were evident, the effects of gibberellic acid concentration (GA_3), temperature and period were evaluated using orthogonal polynomials.

RESULTS

For the shoot dry matter variable, the interactions between rice cultivar, GA_3 and growth temperature did not show any clear trend of variation during the evaluation period (Figure 1). At 3 DAS and 15°C, the SCS-112 cultivar presented the maximum dry matter allocation to shoots at increasing GA_3 up to 300 mg L^{-1} (Figure 1A). The BRS-7 Taim cultivar showed a linear increase up to 750 mg L^{-1} GA_3. In contrast, the cultivar IRGA 417 showed a decrease in the dry matter with increasing GA_3, and BR IRGA 410 did not respond to treatment with gibberellic acid, an attribute of the dry matter in the aerial part.

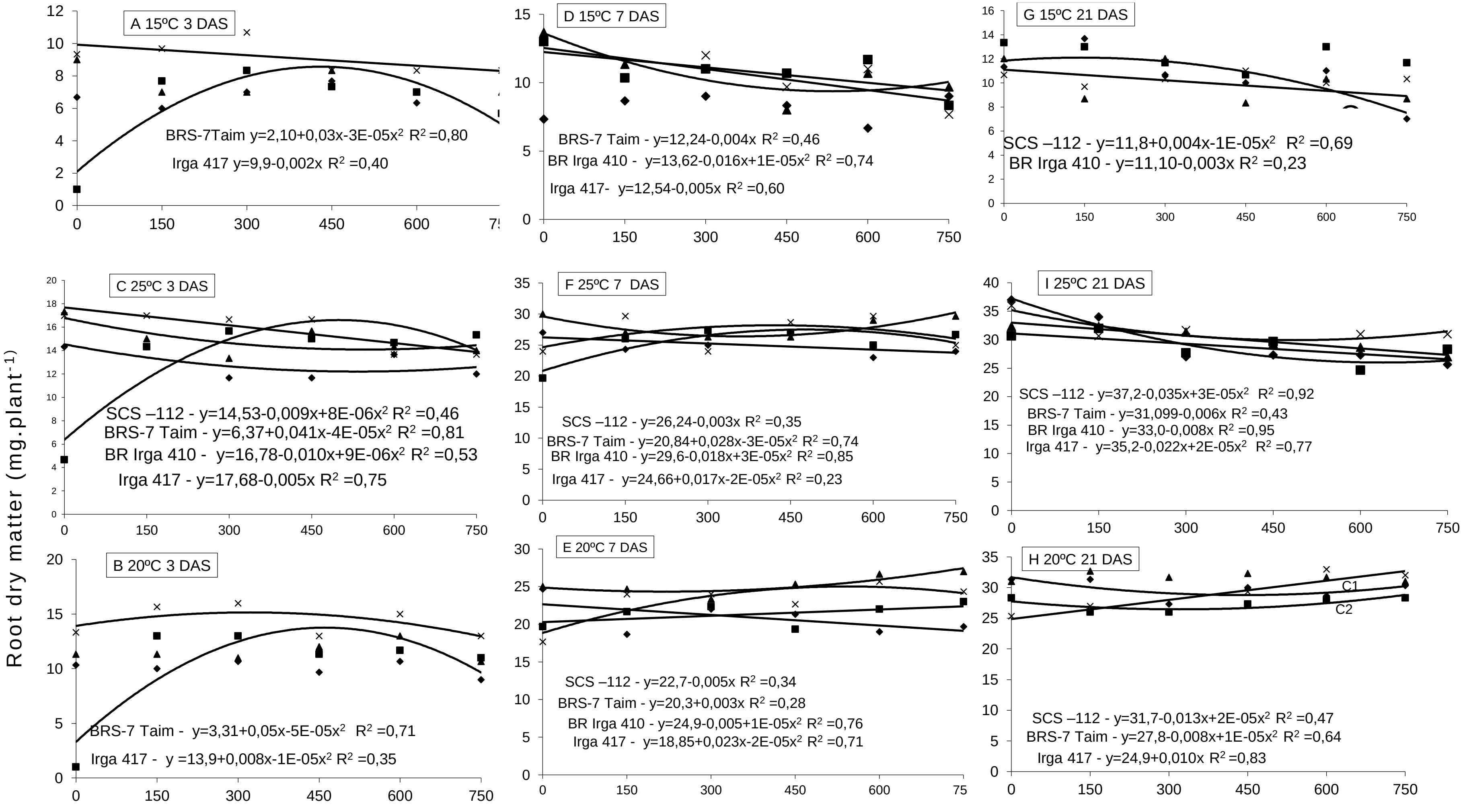

Figure 2. Effect of gibberellic acid (AG3) concentrations on dry matter of the seedlings of the cultivars SCS-112, BRS-7 Taim, BR Irga 410, Irga 417 under temperatures of 15 ° C, 20 ° C and 25 ° C at 3 ° C , 7 and 21 days after sowing (DAS).Figura 2. Efeito das concentrações de ácido giberélico (AG3) na matéria seca das mudas das cultivares SCS-112, BRS-7 Taim, BR Irga 410, Irga 417 sob temperaturas de 15 ° C, 20 ° C e 25 ° C a 3 ° C, 7 e 21 dias após a semeadura (DAS).

When raising the temperature to 20 ° C the cultivars SCS-112, BRS-7 Taim and IRGA 417 displayed differentiated increments in dry matter allocation (Figure 1B). At approximately 450 mg L^{-1} gibberellic acid, BRS-7 Taim showed greater carbon allocation to the aerial part compared to the other cultivars. IRGA 417 and SCS-112 presented a lower response to variation in GA_3, revealing a maximum response point at around 350 mg L^{-1}. In contrast, the cultivar BR IRGA 410 was not affected by the treatment of the seeds with gibberellic acid.

At 25°C and 3 DAS, the cultivar SCS-112 showed a reduction in the dry matter allocation to the aerial part at around 450 mg L^{-1} gibberellic acid, and consequently, tended to increase its growth parameter (Figure 1C). The cultivar BR IRGA 410 showed a small and similar increase to IRGA 417, with a subsequent tendency to reduce the dry matter to the aerial part at GA_3 above 400 mg L^{-1}.

At 7 DAS, the cultivars presented distinct behaviors in the dry matter allocation to the aerial part at the growth temperatures and GA_3 tested (Figure 1D, 1E and 1F). There was a lower response intensity than at 3 DAS, both for GA_3 and temperature (Figure 1A, 1B and 1C).

However, when there was an increase in temperature to 20°C, the cultivars showed points of maximum response and distinct differences in dry matter increments (Figure 1E). The cultivars SCS-112, BRS-7 Taim, BR IRGA 410 and IRGA 417 showed a respective 5, 16, 16 and 67% increase in dry matter allocation, and Meaning the GA3 at which the maximum response occurred, was influenced by the cultivar type.

At 25°C and 7 DAS, the cultivars SCS-112, BRS-7 Taim and IRGA 417 displayed similar behavior to that observed at the lower temperatures, with dry matter increments of 28, 38 and 16%, respectively (Figure 1F). However, the reduction in dry matter allocation at higher GA_3 was less marked than the previous temperature of 20°C.

At 15°C to 21 DAS, there was a corresponding 21, 25 and 18% increase in shoot dry matter allocation for cultivars SCS-112, IRGA 417 and BRS 7 Taim, at approximately 300, 600 and 750 mg L^{-1} gibberellic acid, respectively (Figure 1G), On the contrary, for cultivar BR IRGA 410, there was a negative effect on the allocation of dry matter to the aerial part, with increasing GA_3 up to about 450 mg L^{-1}.

As the temperature was raised from 15 to 20°C, there was a tendency of reduction in the increase of dry matter to the aerial part as a function of the variation in GA_3 (Figure 1H). Analyzing Figure 1I, it was evident that at 25°C, there was a trend towards stabilization in the dry matter allocation to the aerial part of the seedlings with increasing GA_3, although the additions were linear.

For the root dry matter variable, there was an interaction between the cultivar type, GA_3 and growth temperature, which varied according to the evaluation period.

At 3 DAS, the cultivars responded differently to the temperature factor, evaluated as a function of increasing GA_3. At 3 DAS, the cultivar BRS-7 Taim evidenced its lowest sensitivity to exogenously applied gibberellic acid. Conversely, this could also indicate the maximum endogenous amount of gibberellin present in the seed in the initial stages of the resumption of embryo growth, as also verified by the aerial part dry matter results. However, at 7 DAS, the response to GA_3 treatment was less significant at 20 and 25ºC, and absent at 15ºC (Figure 2D, 2E and 2F).

At 3 DAS, the cultivar BRS-7 Taim presented increases of 390% at up to around 450 mg L^{-1} GA_3, corresponding to the point of maximum dry matter allocation to the root. In contrast, the cultivars SCS-112 and BR IRGA 410 were not affected by the gibberellic acid and temperature treatments in the evaluation performed, while the IRGA 417 cultivar showed a linear decrease in the dry matter allocation with increasing GA_3.

At 20°C, the cultivar IRGA 417 showed a low-intensity response, while the cultivars SCS-112 and BR IRGA 410 maintained the same behavior for root dry matter to that observed as a function of GA_3 at 15°C. Thus, the cultivars did not respond positively to the gibberellic acid treatments at 20°C (Figure 2B) because adequate temperatures are sufficient to improve the physiological performance of seeds and seedlings, increase efficiency in the activation of enzymatic metabolism and facilitate rapid cell reorganization (PESKE et al. 2012).

At 15°C, it was observed that all cultivars presented an inhibitory effect and similar intensity in the root dry matter allocation with the increase in GA_3 (Figure 2D). As the temperature was raised to 20ºC, differentiated behavior occurred for the cultivars as a function of the GA_3 (Figure 2E). At 25°C, cultivars BRS-7 Taim and IRGA 417 maintained minor increases in the dry matter allocation to the root, of 25 and 6%, respectively, with a corresponding maximum response point at 450 and 350 mg L^{-1} GA_3, at 7 DAS (Figure 2F).

At 7 DAS, BRS-7 Taim continued to exhibit endogenous gibberellin deficiency and responded with less magnitude to the effect of exogenous application of GA_3 via the seed, compared to 3 DAS. This may be mainly because gibberellic acid stimulates the cell wall plasticity and the hydrolysis of starch into sugars (TAIZ & ZEIGER, 2009). At 21 DAS and 15°C, the cultivars SCS-112 and BR IRGA 410 underwent a decrease in the dry matter of the root with increasing GA_3, whereas the cultivars BRS-7 Taim and IRGA 417 did not respond to the presence of the growth regulator. Increasing the temperature to 25°C at 21 DAS, yielded a tendency for all cultivars evaluated, to reduce the dry matter allocation with increasing GA_3. However, cultivars IRGA 417 and SCS-112 showed more pronounced reductions at lower GA_3, with a tendency to stabilize dry matter allocation to the roots at the highest concentrations.

DISCUSSION

It is possible that these differential outcomes in the accumulation of dry matter of rice seedlings are because gibberellic acid induces responses in the elongation, cell division and expression of the α-amylase gene, which is important for the resumption of growth of the embryo in cereals (CARRAHER JR. et al. 2010).

The greater negative effect on the allocation of dry matter to the aerial part with increasing GA_3 may be associated with the location of the synthesis of this phytohormone in these structures. Although all tissues have the potential to produce any phytohormone, the production is regulated by environmental factors and exerting inductive effects for changes in metabolism and phytohormone distribution within the plant (MIR et al. 2010: SZARESKI et al., 2018).

In this context, it should be emphasized that the response of the vegetable to the exogenous application of growth regulators is dependent on tissue sensitivity, stage of development and applied dose (TAIZ & ZEIGER, 2009).

The higher growth, due to the increased allocation of dry matter, is associated with a greater ability to reorganize the cell membrane system, a lower electrolyte extravasation to the external environment, and a superior efficiency in conversion, translocation and assimilate allocation to the seedling (PESKE et al. 2012). In addition, it is linked to the maximization of drain strength that is accentuated by the action of cytokinins, plant hormones that act in synergism with the gibberellins, and which, can provide the expansion and increase in cell wall extensibility (TAIZ & ZEIGER, 2009).

Plant growth regulators alter diverse physiological processes, even when present at very low concentrations (TAIZ & ZEIGER, 2009). Thus, the tendency of reduction in the allocation of dry matter to the aerial part and roots may be linked to the application of very high doses of gibberellic acid or may be indicative of a supra-optimal GA_3 for some of the cultivars studied. Together, it is possible that in rice cultivars without response to the treatment of seeds with gibberellic acid, the endogenous level of gibberellins is within the amount necessary to activate physiological processes associated with the expression of seed vigor.

CONCLUSION

From the results, it is possible to verify that the cultivars of irrigated rice show distinct responses to the GA_3, as a function of the growth temperature and the evaluation period. The best performance in the initial growth of seedlings exposed to gibberellic acid demonstrates the greater expression of the vigor of rice seeds and shows the superiority in the efficiency of the different physiological processes involved in the resumption of embryo growth. This was particularly evident for the cultivar BRS-7 Taim, which presented an intense response to the exogenous application of gibberellic acid at up to 450 mg L^{-1}.

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